OPTIMIZATION OF THE
ST. PASCAL
WATER TREATMENT PLANT
FOR CONTROL OF TRIHALOMETHANES

NOVEMBER 1998

Ontario

Ministry
of the
Environment

ISBN 0-7778-7970-0

Optimization of the
St. Pascal
Water Treatment Plant for Control of Trihalomethanes

Prepared for
Ministry of the Environment
Standards Development Branch

November 1998

Cette publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1998
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 3707E

EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the new Ontario Drinking Water Objectives (ODWO) THMs guideline without compromising disinfection.

2. Sustaining long term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THMs objective without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The optimization of the St. Pascal Water Treatment Plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of chemicals for disinfection and making changes to plant operation.

EXISTING CONDITIONS

St. Pascal is a small community of approximately 350 residents located in Clarence Township south east of Ottawa. Its water supply is obtained from one of two drilled wells located on Lots 9 and 10 of Concession V. The well on Lot 10 is the main production well while the other well of low yield is only used in a stand-by mode. The production well and treatment plant were made operational in April 1992. The treatment plant is located 1.2 kilometers from the production well. The plant is owned and operated by the Township of Clarence.

The raw water characteristics are:

Colour:	54 to 97 TCU
Turbidity:	0.7 to 9.0 NTU
pH:	7.2 to 8.5
Alkalinity:	562 to 574 mg/L
TOC:	10.4 to 12.6 mg/L

Plant flows are generally:		
	Average daily flow	148 m^3/d (1995)
	Maximum daily flow	280 m^3/d (1995)
	Plant rated capacity	544 m^3/d

The water treatment plant consists of:

- ⇒ Well No. 1 (production well), and Well No. 2 (standby well).
- ⇒ Raw water supply main to the treatment plant.
- ⇒ One aeration chamber.
- ⇒ Two low lift pumps.
- ⇒ Two GAC contactors in series.
- ⇒ Hydrogen peroxide injection into the wells.
- ⇒ Sodium hypochlorite injection into the clearwell.
- ⇒ Two vertical turbine high lift pumps.

PERFORMANCE ASSESSMENT

Before construction of the plant in 1992, an experimental treatment study had been performed for the St. Pascal groundwater supply to evaluate the feasibility of raw water treatment with granular activated carbon (GAC). The results showed that the GAC was capable of providing high quality drinking water meeting all Ontario Drinking Water Objectives (ODWO). Passage of the raw water through a bed of granular activated carbon removed most of the colour and produced water with a much lower chlorine demand which was easily further decoloured by free chlorine bleaching.

Good water quality was initially obtained for approximately three months and then the finished water quality deteriorated rapidly with colour and odour problems. After several months of operation the treated water colour had risen to the same level as the raw water, showing the carbon was inactive or exhausted and was no longer adsorbing organics. In addition to the high water colour, the THMs concentrations in the treated water were found to be very high, approaching 900 μg/L.

After about one year of operation, problems with the operation of the well became apparent. Biological growth was choking the well pump and pipe to the plant, the aeration chamber and the wetwell. Use of chlorine to kill the growth was considered knowing that it would be only partly effective, and would have effects on the downstream carbon contactors and possibly reduce their life span.

Hydrogen peroxide was tried as an alternative to pre-chlorination in 1994. An injection system was set up and 140 mg/L hydrogen peroxide was used to control the biofilm formation. Maintenance doses of 15 mg/L were suggested to control growth and odour in the raw water. This appeared to be moderately effective at first in controlling slime and biofilm growth.

The estimated cost for the replacement of the two GAC contactors is $20,000 per recharge, and four replacements were predicted per year although these were not carried out due to high costs. In response to medical concerns the carbon was replaced in early 1996. Water of acceptable but gradually deteriorating quality was in production early in the summer 1996.

RECOMMENDATIONS

After a site visit to the St. Pascal Water Treatment Plant in June 1996, it was decided, with the operators, that economic operation producing acceptable water quality would depend on the success or failure in the application of two basic techniques.

1. Enhancement of the carbon adsorption capabilites to reduce operating cost associated with its replacement. It was recommended that the GAC contactors be operated as biologically active filters to extend their useful period of operation, and to reduce the concentration of organics in the treated water. In turn, the reduced amounts of organics will produce less THMs after chlorine addition for disinfection.

2. Use of chloramine disinfection as opposed to use of free chlorine to provide a much better control on THMs formation.

Biological Carbon

When exposed to a wide range of chemicals, the carbon surface adsorbs a layer of molecules by weak chemical attachment. When all accessible surfaces are covered, the carbon is said to be spent or to have exhausted its adsorption capacity. The carbon then requires removal and disposal or heat treatment for regeneration. This adsorption process is purely physical/chemical and does not involve activity of micro-organisms. The adsorption process will last a few months to two years depending on the carbon type, the amount of water passing through, and the type and concentration of contaminant.

Carbon can also be used to support micro-organism growth and activity. Instead of relying solely on the adsorption capacity of the carbon, favorable conditions can be developed to promote growth of micro-organisms which will use the organics as food, extending the life span. The micro-organisms are non-harmful bacteria and can also be found in a thin layer on the walls of most water mains. Given enough time and nutrients, the bacteria film will digest much of the organics in the water.

The biological process will increase the bacteria mass over time to a point that can block the passage of water through the filter. To reduce the clogging of the carbon bed, backwash is used to dislodge looser masses of bacteria. Eventually, regular backwashes will fail to bring back bed performance due to the total saturation of the carbon. The carbon will then need to be replaced.

Since the plant design includes two contactors operated in series, the practice of reversing the order of contactors after staggered bed replacement was recommended.

Chloramination

Ammonia combines chemically with chlorine to produce a lower strength disinfectant, monochloramine, also called chloramine. Use of chloramine has two consequences relevant to drinking water quality. These are as follows:

1. Chloramine does not react with organics present in the water to form THMs.
2. Chloramine is a less powerful disinfectant than free chlorine and care must be taken to ensure this factor does not affect water quality.
3. Chloramine will maintain a residual in the distribution system for a longer period of time than free chlorine.

Chloramine alone is generally not considered powerful enough for surface water disinfection even with hours of contact at high concentrations. With groundwater, disinfection requirements are easier to achieve since the more resistant micro-organisms to disinfection like cysts are removed as the water percolates down to the aquifer.

The raw water supply contains some ammonia probably resulting from local fertilizer use above the aquifer. Based on observations made during the summer of 1997, when chloramination was performed at the plant, the addition of ammonia was not required since there was sufficient concentration to provide adequate levels of chloramine. Therefore, depending on the time of the year, addition of ammonia may not be required. The chloramine treatment has proved entirely satisfactory, producing consistant THMs concentrations under 10 µg/L.

Oxidation

Control of biological growth in the St. Pascal well and connecting system to the carbon adsorbers was achieved before the THMs control study. Excessive quantities of peroxide were found to be needed when added continuously. Previous rates of addition at 10 to 15 mg/L were apparently supporting aerobic biofilm activity. As a consequence peroxide levels were reduced and maintained at about 2 mg/L at the plant to control odours. Failure to maintain the peroxide residual rapidly resulted in a sulphur odour probably due to anaerobic activity. With a dosage of 15 mg/L a gradual thickening of the biofilm was taking place causing deterioration of the water quality.

Hydrogen peroxide is known to serve as an oxygen supply for bacteria at concentrations below 50 mg/L. Treatment with greater concentrations of peroxide was needed to clear the biofilm from time to time. Regular shock loading at approximately 100 mg/L is now being performed once a week at the well head. This requires less than half the amount of peroxide to provide 10 mg/L continuous dosing and is much more effective in biofilm control and odour prevention. Care is required not to overdose and affect biofilm activity in the carbon contactors.

CONCLUSIONS

The MOE in cooperation with RAL Engineering Ltd. had the mandate to develop and demonstrate cost effective operating procedures and treatment processes to improve the quality of drinking water, and has done so in carrying out the THMs optimization study.

During 1996 and 1997 the St. Pascal Water Treatment Plant was operated with the MOE assistance to optimize use of existing equipment and chemicals and to modify the disinfection procedures to avoid THMs formation. The changes instituted produced water with very low THMs concentrations.

Work carried out with the full cooperation of St. Pascal water plant staff and management has led to the following results:

- Control of THMs levels to well below the current limit of 100 µg/L has been shown possible using injection of small amounts of ammonium sulphate to perform chloramination. The results for water samples taken in July and August 1996 showed only a trace level of THMs at the water treatment plant and in the distribution system. The dosing equipment as well as water sampling tap is in place. Injection of ammonium sulphate was not needed during the summer 1997 due to natural ammonia levels, however, this may change periodically. Equipment required for ammonium sulphate injection is installed and ready for use.
- The plant can be successfully operated with the carbon beds in biological mode. Under this condition, acceptable treated water with colour below 25 TCU can be obtained from the beds over at least 9 months and possibly for one year before replacing the carbon.
- A carbon replacement was required in the fall of 1997 after only four months of operation. It is suspected that the type of carbon used during the last replacement was not suitable to support biological growth. Care should be given in the future to ensure the right type of carbon is selected.
- The turbidity of the treated water during the summer of 1996 ranged from 0.2 to 0.27 NTU with an average of 0.23 NTU. This is below the ODWO for turbidity of 1 NTU. Current US research and experience now indicates that a turbidity of 0.1 NTU in filter effluent is needed to provide protection from cryptosporidium. However, with the source of raw water being a deep well , the presence of cryptosporidium is unlikely.
- The performance of hydrogen peroxide applied to control biofouling in the well and raw water pipes has improved by using regular shock treatment rather than continuous addition.

OPERATING COSTS ESTIMATE

By operating the GAC contactors in biological mode, acceptable finished water can be obtained for at least 9 months before replacing the carbon in the beds. The costs for bed replacement to maintain an acceptable treated water quality would be $20,000 per year compared to $80,000 per year if operated strictly as physical adsorbers and replaced quarterly.

The additional operating cost related to dosing ammonium sulphate can not be estimated accurately since the exact dosage required and the actual period of the year when its addition is required is not known. This is due to the fact that the ammonia concentration in the raw water is not constant through the year. The chemical costs, if any, would be very modest.

Adjustments in the manner of use of the hydrogen peroxide applied to control biofouling by using regular shock treatment rather than continuous addition is likely to reduce peroxide usage to less than 50% of the current rate for a saving of about $20,000 per year.

Work undertaken during the THMs optimization study in 1996 and 1997 demonstrated that the St. Pascal plant can be operated to produce safe water at reduced but still considerable operating costs.

OPTIMIZATION
of the
ST. PASCAL
WATER TREATMENT PLANT
for
CONTROL OF TRIHALOMETHANES

TABLE OF CONTENTS

EXECUTIVE SUMMARY E-1

TABLE OF CONTENTS

PAGE

1.0 BACKGROUND 1

2.0 OBJECTIVES 3

3.0 DOCUMENTATION OF EXISTING CONDITIONS 4
- 3.1 The Treatment Process 6
  - 3.1.1 Production Well No.1 6
  - 3.1.2 Standby Well No.2 6
  - 3.1.3 Aeration Chamber 7
  - 3.1.4 Low Lift Pumps 7
  - 3.1.5 GAC Contactors 7
  - 3.1.6 Clearwell 8
  - 3.1.7 High Lift Pumps 8
  - 3.1.8 Wastewater Disposal 8
- 3.2 Chemical Feed Systems 9
  - 3.2.1 Oxidation 9
  - 3.2.2 Disinfection 9
- 3.3 Flow Measurement 10
- 3.4 Historical Data 10

4.0 PERFORMANCE ASSESSMENT 16
- 4.1 July and August 1996 Water Sampling 16
- 4.2 Process Unit Assessment 20

5.0 PROCESS MODIFACTIONS 22
- 5.1 THMs Control 22
  - 5.1.1 Precursors Removal 22
  - 5.1.2 Chloramination 25
- 5.2 Oxidation 27

6.0 CONCLUSIONS 29

7.0 OPERATING COSTS ESTIMATE 31

GLOSSARY AND LIST OF ABBREVIATIONS

REFERENCES

APPENDICES

APPENDIX A Plant Survey

APPENDIX B Analytical Procedures used by Novamann

APPENDIX C Certificate of Approval

APPENDIX D Operating Procedures

LIST OF TABLES

3.1 St. Pascal WTP Historical Water Quality Results for 1994-1995 11

4.1 July and August 1996 Sampling for St. Pascal WTP - Novamann Results 18

4.2 July and August 1996 Sampling for St. Pascal WTP - Operating Data 19

LIST OF FIGURES

3.1 St. Pascal Water Treatment Plant Schematic 5

3.2 Turbidity for St. Pascal WTP 14

3.3 Colour for St. Pascal WTP 15

1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (eg. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often has high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

- Free chlorine concentration - higher Cl_2 = higher THMs
- Organic content - higher organic concentration = higher THMs
- pH - higher pH = higher THMs
- Temperature - higher temperature = higher THMs
- Time - normally longer time = higher THMs

The formation of trihalomethanes is associated with the presence of organics in the water. This is often the case in inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff. It can also occur when groundwater sources draw water from aquifers high in organics.

The reason for adding chlorine to drinking water is to kill bacteria and other microorganisms that could cause numerous illnesses. However chlorine use leads to the presence of trihalomethanes and this is a cause for concern; studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from an "anytime" maximum acceptable concentration of 350 μg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 μg/L based on a running annual average of four quarterly samples.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities which are shared by all suppliers of food or drink. Owners and suppliers must take reasonable measures to ensure the water is fit for safe consumption.

This optimization study is funded by the Ontario Ministry of Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities such as St. Pascal should be capable of producing water that meets the new THMs objective, without resorting to costly upgrades. The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of each process unit.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THMs, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF ST. PASCAL WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below:

  i To comply with the 100 μg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.

  ii To investigate possible methods of reducing high costs associated with frequent replacement of GAC.

  iii To investigate methods of reducing or eliminating well pump and raw water pipeline fouling and water quality deterioration with biofilm by more economical use patterns of hydrogen peroxide.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term in response to raw water quality variations.
- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

St. Pascal is a small community of approximately 350 residents located in Clarence Township south east of Ottawa. Its water supply is obtained from two drilled wells located on Lots 9 and 10 of Concession V. The well on Lot 10 is the main production well while the other well of low yield is only used in a stand-by mode. The production well and treatment plant, which is located 1.2 km away from the well, were made operational in April 1992. The plant is owned and operated by the Township of Clarence. There were two operators on staff working approximately one to two hours per day. A plant survey was performed during a site visit on June 12, 1996 to prepare a detailed description of the existing equipment and the condition of operation. The survey is documented in Appendix A, and a copy of the Certificate of Approval is presented in Appendix C. A plant schematic is presented in Figure 3.1.

The raw water characteristics are:

Colour: 54 to 97 TCU
Turbidity: 0.7 to 9.0 NTU
pH: 7.2 to 8.5
Alkalinity: 562 to 574 mg/L
TOC: 10.4 to 12.6 mg/L

Plant flows are generally:

Average daily flow	148 m^3/d (1995)
Maximum daily flow	280 m^3/d (1995)
Plant rated capacity	544 m^3/d

The water treatment plant consists of:

- ⇒ Well No. 1 (production well), and Well No. 2 (standby well).
- ⇒ Raw water supply main to the treatment plant.
- ⇒ One aeration chamber.
- ⇒ Two low lift pumps.
- ⇒ Two GAC contactors in series.
- ⇒ Hydrogen peroxide injection into the wells.
- ⇒ Sodium hypochlorite injection into the clearwell.
- ⇒ Two vertical turbine high lift pumps.

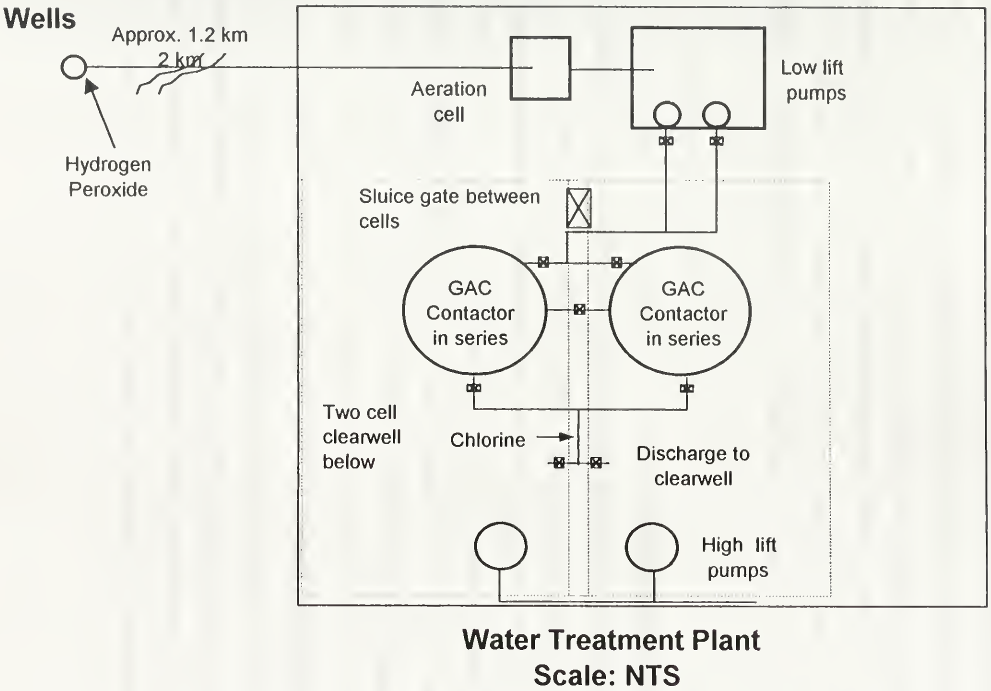


FIGURE 3.1 St. Pascal Water Supply Schematic

3.1 THE TREATMENT PROCESS

At the treatment plant, water is passed over a series of baffle plates installed in the aeration chamber to strip volatiles. From there, the water enters a low lift chamber where it is re-pumped through two activated carbon pressure contactors containing 5.72 m^3 of carbon each. The water is discharged into a clearwell for final disinfection with sodium hypochlorite and is then pumped into the distribution system. The distribution system is effectively linear with one pressure zone. There is no elevated storage in Town. The demand is met by one variable speed high lift pump with a second pump on standby. The treatment plant is equipped with a 60 kW Leroy stand-by power diesel generator set, a 912 litre fuel tank with a concrete containment facility, fuel piping system and exhaust gas system and controls.

3.1.1 Production Well No. 1

Well No.1 is the main well and it is housed in a pumping station located on Lot 10, Concession 5. The well is equipped with a submersible pump having a capacity of 5.7 L/s, standby chemical feed system consisting of a chemical pump capable of dosing sodium hypochlorite or hydrogen peroxide at a rate of 4 L/h, and a solution tank. The raw water is normally supplied by Well No.1. Well No.2 would be used only if the production from Well No.1 is interrupted. There is no standby generator at the well head.

3.1.2 Standby Well No.2

Well No.2 is housed in a pumping station located on Lot 10, Concession 4. The well is equipped with a submersible pump having a capacity of 5.7 L/s, standby chemical feed system consisting of a chemical pump capable of dosing sodium hypochlorite solution or hydrogen peroxide at a rate of 4 L/h, and a solution tank.

3.1.3 Aeration Chamber

The aeration chamber consists of a 6.2 m^3 concrete tank equipped with four staggered steel plates having an effective surface area of 2.6 m^2 to provide cascade aeration to volatiles. The chamber provides a detention time of 15 minutes at the plant rated capacity of 6.3 L/s. Under present operation, the two Aerovent air blowers associated with the aeration chamber are not used. The performance of the aeration chamber without additional aeration is sufficient to remove any gases present in the raw water.

3.1.4 Low Lift Pumps

A 29.4 m^3 below grade wetwell is equipped with two (2) low lift vertical turbine pumps (one on duty and one on standby), each having a rated capacity of 6.3 L/s. A flow control valve on the pump discharge is used to reduce the rate of pumping to approximately the maximum day demand. Provision had been made for the pre-chlorination of the wetwell if required. A level system installed in the wetwell controls the on/off operation of the low lift pumps. The operation of the well pumps is controlled by the level in the main clearwell.

3.1.5 GAC Contactors

The treatment plant is equipped with two (2) down flow pressurized granular activated carbon (GAC) contactors, each with a downflow design capacity of 6.4 m/h at plant rated capacity (6.3 L/s), and a design Empty Bed Contact Time (EBCT) of 15 minutes. The GAC contactors are used to reduce the colour (ie. THMs precursors) in the water prior to chlorination. The GAC contactors operate in series and are equipped with sample taps to monitor performance. Each contactor contains 5.72 m^3 of carbon. The overall dimensions of each contactor is approximately 2.13 m (7') in diameter and 2.3 m (7.6') high. The nominal bed depth is 1.6 m.

The contactor system is equipped with a piping system that allows the sequence of the contactors to be reversed. The piping and valving provide control of pressure and allows automatic or manual backwashing. There is a filter backwash pump rated at 21.1 L/s to provide a maximum bed expansion of 70%.

3.1.6 Clearwell

There is a two-celled underground clearwell which has a total volume of 428 m^3. The overall dimensions of the clearwell are 12 m long 5.95 m wide 3 m deep for each cell. The water level in the clearwell varies between 2.75 and 2.92 m. The clearwell is equipped with level sensors which control well pump operation. The two cells have no baffles, but the flow can be routed from the GAC contactor effluent to the end of one cell down the length through a gate and back to the high lift pump reducing potential for short circuiting of the flow. There is no other storage capacity available to the community.

3.1.7 High Lift Pumps

The clearwell is equipped with two (2) variable speed vertical turbine high lift pumps (one on duty and the other on standby), each capable of delivering water to the existing distribution system within a range of 2.5 L/s (average flow) to 16.07 L/s (peak hour). The Worthington turbine pumps are driven by 21.6 kW (29 HP) U.S. Electric motors.

3.1.8 Wastewater Disposal

The filter backwash and sewage disposal system consists of a 25,000 litre capacity holding tank, two (2) submersible sewage pumps each rated at 2 L/s, a 2,700 litre capacity septic tank and a tile field.

3.2 CHEMICAL FEED SYSTEMS

The chemical feed systems at the beginning of the optimization study were:

Process Function	*Chemical*	*Locations Added*
Oxidation/Biocide	Hydrogen peroxide	Well No.1
Disinfection	Sodium Hypochlorite	Clearwell Inlet-GAC effluent

3.2.1 Oxidation

Chlorination was initially practised at the well head, in the low lift chamber, and at the clearwell inlet. The chlorine proved to be ineffective at controlling the biofouling throughout the system. Very heavy slime deposits could be observed in any exposed areas and the odour of the raw water deteriorated probably due to bacterial activity. The carbon columns quickly lost the ability to adsorb the large organic molecules that contributed to the colour. Biofouling of the carbon was very evident upon inspection. In the distribution system, high bacterial counts were reported routinely by the Ministry of Environment laboratory in Kingston.

Currently, hydrogen peroxide is fed at the well at a concentration of approximately 75 mg/L. This is done by preparing a batch solution of 40 L injected into the well every week. Continuous dosing of hydrogen peroxide had effectively controlled the slime-forming micro-organisms, however, this practice had significantly increased the operating costs.

3.2.2 Disinfection

Post-disinfection is provided by the introduction of a 12% sodium hypochlorite solution into the GAC contactor discharge conduit to the clearwell. The water treatment plant is equipped with a chemical feed room containing three (3) chemical feed pumps each capable of dosing sodium hypochlorite solution at a maximum rate of 4 L/h, and three chemical solution tanks each having a capacity of 228 litres and fitted with a mixer and piping system. The chemical feed pumps are ProMinent 44 positive displacement units. The applied dosage in the summer of 1996 ranged from 12 to 15 mg/L.

3.3 FLOW MEASUREMENT

A Water Specialties turbine meter is installed on the discharge header from the two low lift pumps, and one Water Specialities turbine meter measures the flow of treated water to the distribution system. A Honeywell circular chart recorder is used to monitor flow.

3.4 HISTORICAL DATA

A summary of historical data from February 1994 to October 1995 is presented in Table 3.1, which summarizes average values for turbidity, colour, pH, sodium, ammonia, aluminum residual and THMs found in the water. The range and annual average from the data in Table 3.1 are summarized below:

Parameters	*Units*	*Range*			*Average*
Turbidity - Raw Water:	NTU	0.70	to	9.08	2.58
Turbidity - Treated Water:	NTU	0.33	to	0.95	0.50
Colour - Raw Water:	TCU	54	to	97	77
Colour - Treated Water:	TCU	26	to	42	33
pH - Raw Water:		7.2	to	8.5	8.1
pH - Treated Water:		7.8	to	8.4	8.2
Sodium - Raw Water:	mg/L	196.9	to	256.0	227.0
Sodium - Treated Water:	mg/L	216.0	to	259.9	236.0
Ammonia - Raw Water:	mg/L	0.54	to	0.89	0.74
Ammonia - Treated Water:	mg/L	0.01	to	0.03	0.02
Aluminum - Raw Water:	µg/L	5.3	to	6.0	5.7
Aluminum - Treated Water:	µg/L	7.2	to	9.0	8.1
THMs - Distribution System:	µg/L	451	to	533	483

TABLE 3.1 ST. PASCAL WATER TREATMENT PLANT
HISTORICAL WATER QUALITY RESULTS
WATER SAMPLES ANALYZED FOR THE DRINKING WATER SURVEILLANCE PROGRAM (DWSP)

	COLOUR (TCU)		TURBIDITY (NTU)		pH		SODIUM (mg/L)		AMMONIA (mg/L-N)		Aluminum (ug/L)	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Feb-94	84	39	0.70	0.35	8.1	8.1	221.4	237.8	0.72	0.02	-	-
May-94	97	42	0.95	0.40	8.0	8.2	213.9	231.0	0.87	<0.01	-	-
Aug-94	67	-	9.08	-	8.5	-	248.0	-	0.74	-	6.0	7.2
Sep-94	78	34	2.59	0.47	8.1	8.1	244.0	248.1	0.58	0.01	-	-
Feb-95	97	32	1.20	0.95	7.2	7.8	196.9	223.3	0.89	<0.01	5.3	9.0
Jun-95	63	26	0.95	0.50	8.5	8.4	209.0	216.0	0.83	0.02	-	-
Oct-95	54	27	2.57	0.33	8.3	8.3	256.0	259.9	0.54	0.03	-	-
MINIMUM	54	26	0.70	0.33	7.2	7.8	196.9	216.0	0.54	0.01	5.3	7.2
MAXIMUM	97	42	9.08	0.95	8.5	8.4	256.0	259.9	0.89	0.03	6.0	9.0
AVERAGE	77	33	2.58	0.50	8.1	8.2	227.0	236.0	0.74	0.02	5.7	8.1

Note: The THM measured by the MOE is summarized as follows:

	THM Quenched (ug/L) in the Distribution System
Oct-94	546
Nov-94	533
Dec-94	511
Jan-95	397
Feb-95	451
Apr-95	460

	THM Unquenched (ug/L) at the Water Treatment Plant
Nov-95	649
Dec-95	685

Water used for any community must be disinfected using chlorine or other more powerful chemicals such as ozone as a proven health protection measure against water-borne diseases. The St. Pascal groundwater has a high chlorine demand which means that large amounts of chlorine are required to provide a persistent chlorine residual concentration. Some of the chlorine added for protection reacts chemically with the NOM (natural organic matter), and produces THMs (trihalomethanes).

The water samples taken for THMs analysis were quenched with sodium thiosulfate to remove chlorine residual to stop any further reaction between free chlorine and organics. Quenched water samples taken in the distribution system will maintain the same level of THMs as existed at the time of sampling, thereby representing the quality experienced by the consumer. High levels of THMs were observed through the years for 1994 and 1995 for an average concentration of 483 μg/L which greatly exceeds the new ODWO of 100 μg/L.

In 1994 and 1995 the St. Pascal plant produced highly coloured water with very high THMs concentrations which led to health concerns. Both the Medical Officer of Health and the Regional Office of the MOE became aware of this situation. A public meeting was held at St. Pascal to inform the population that the water as treated was unfit for drinking. The MOE local office further recommended the plant be included for technical assistance in the Ministry THMs optimization study.

The variation of turbidity in the raw and the treated water is presented in Figure 3.2. High levels of turbidity in the raw water ranging from 2.59 to 9.08 NTU was observed for August 1994, September 1994 and October 1995. The turbidity in the treated water varied between 0.33 and 0.95 NTU for an average of 0.5 NTU.

The variation of colour in the raw and the treated water for the St. Pascal Water Treatment Plant is presented in Figure 3.3. The raw water colour reaches its maximum value from February to May with values ranging from 84 to 97 TCU. The treated water colour was always higher than the ODWO at an average of 33 TCU. The raw water also contains a high level of NOM causing the strong yellow brown colour in the raw water.

The historical data from Table 3.1 indicates that the average levels of aluminum residual in the raw water and treated water are 5.7 and 8.1 μg/L respectively, which is much below the ODWO operational guideline of 100 μg/L.

Results also indicate that the sodium level from the treated water averaged 236 mg/L is above the level that would warrant a health advisory to persons on a sodium reduced diet. The MOE guideline for sodium level is 200 mg/L. The groundwater quality in this region of the province, though meeting Ontario Drinking Water Objectives for minerals content, is generally high in sodium, chloride and bromide.

The free ammonia concentration in the raw water varies from 0.54 to 0.89 mg/L for an average of 0.74 mg/L. It is expected that the concentration of ammonia will be reduced by the addition of hydrogen peroxide as well as by biological degradation through the GAC contactors.

The St. Pascal wells are 50 m deep drilled wells with metal casing. The shallow part of the wells contain many metres of non saturated strata with surface water percolation. The risk of contamination by cysts from surface water is not a concern in a groundwater source since the overlying clay and silt layers will act as a natural filter and stop potential contamination. The disinfection requirements for St. Pascal are related to bacteria and viruses that could enter the system.

FIGURE 3.2 TURBIDITY FOR ST. PASCAL WTP

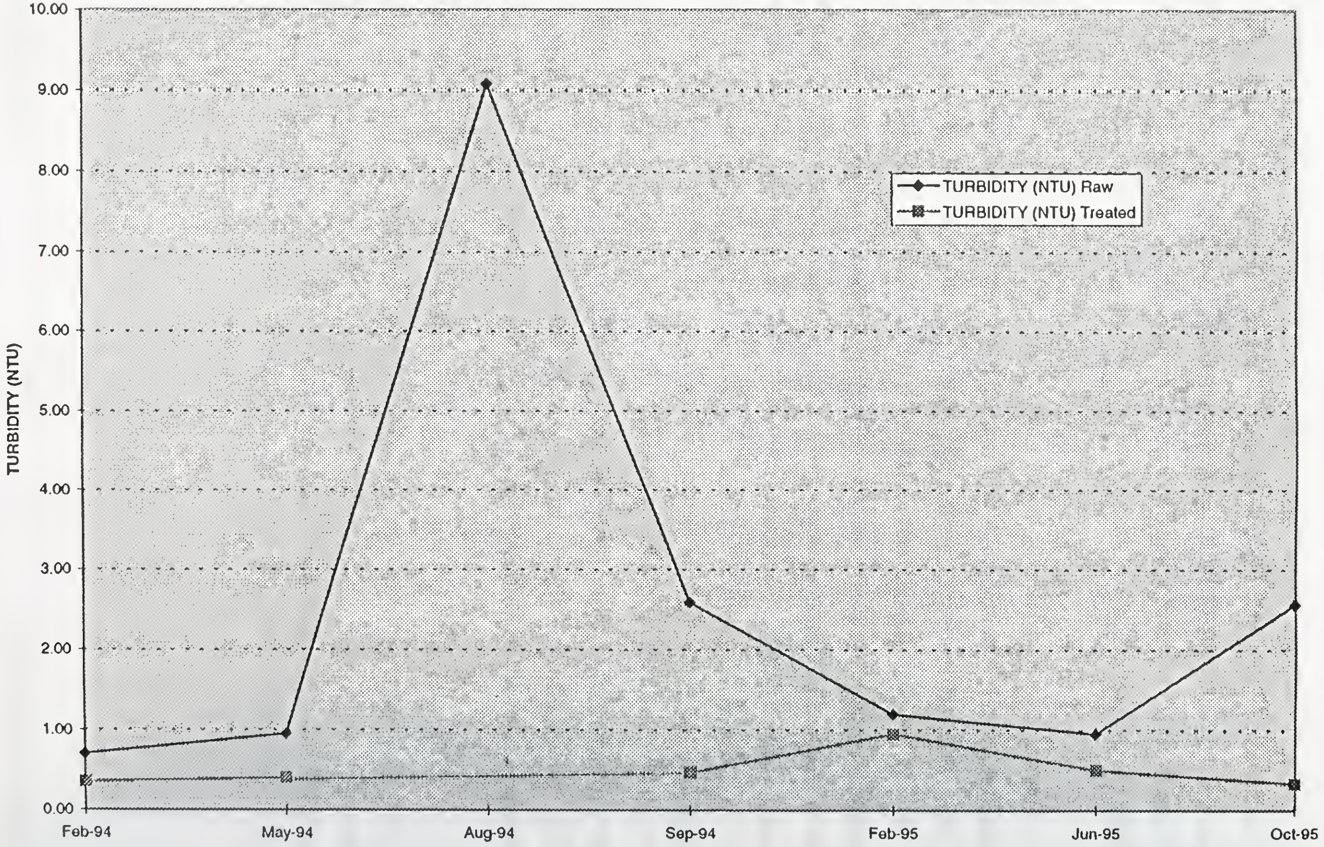
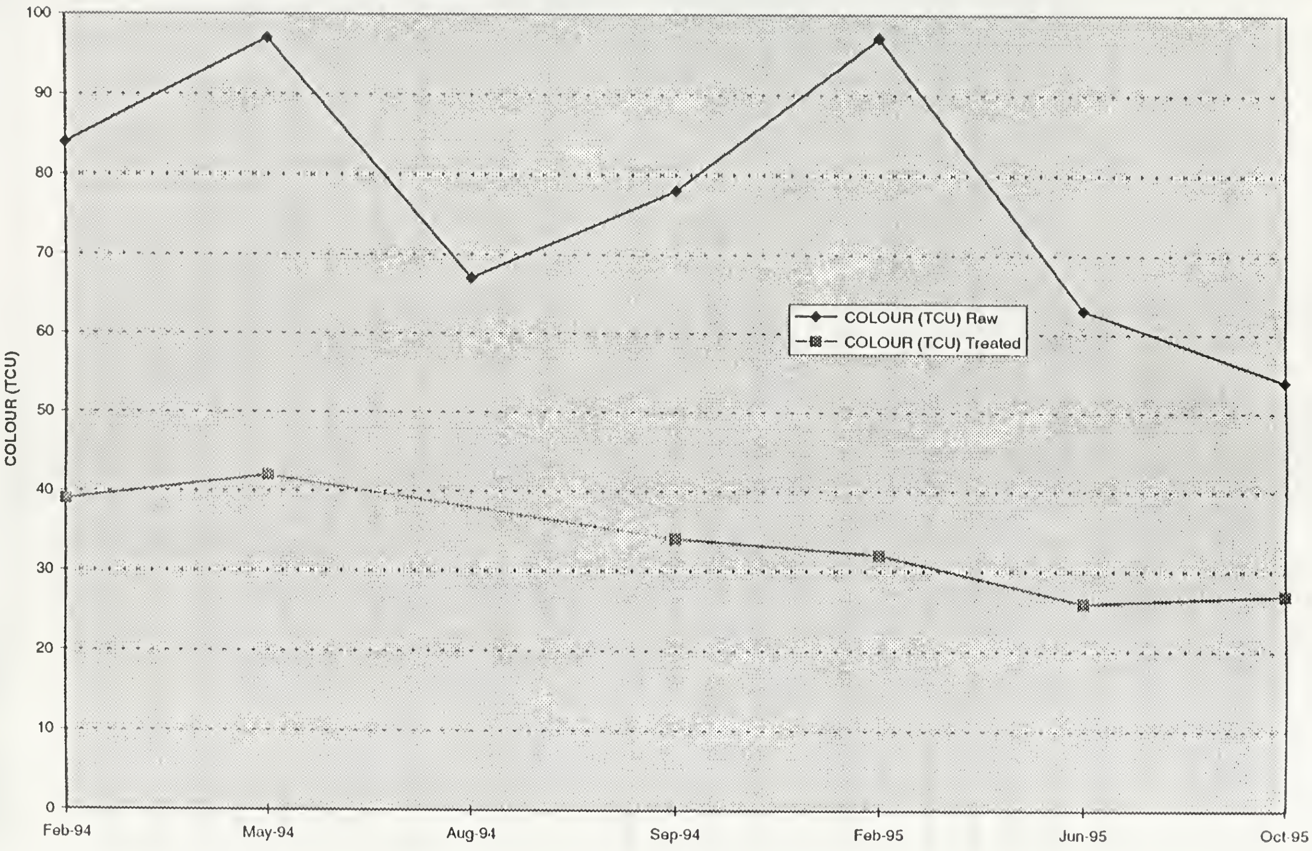


FIGURE 3.3 COLOUR FOR ST. PASCAL WTP



4.0 PERFORMANCE ASSESSMENT

4.1 JULY AND AUGUST 1996 WATER SAMPLING

Additional water samples were collected in July and August 1996 to establish a baseline for THMs formation versus the level of colour and Total Organic Carbon (TOC). The samples were analyzed by Novamann Laboratories Inc. (currently operating under Maxxam Analytics). The detection limit of the analytical procedures and the method reference used by Novamann is summarized in Appendix B. The results obtained from 5 weeks of sampling are summarized in Table 4.1. The operation data collected at the water treatment plant for the days of sampling including average daily flow, turbidity, raw water temperature and chemical dosages are presented in Table 4.2.

The average colour measured during the summer sampling was 60 TCU for the raw water and 22 TCU for the treated water. The groundwater supply is relatively high in colour and the colour in the treated water largely exceeds the MOE guideline of 5 TCU. This is due to the fact that the GAC contactors were becoming saturated with an overall colour removal of approximately 60%.

The average TOC measured during the summer sampling was 12 mg/L for the raw water and 9 mg/L for the treated water hence the overall TOC removal through the GAC was only 25%.

The THMs measured at the water treatment plant and in the distribution system were only present at trace levels for the 5 weeks of sampling. Higher levels, as previously recorded were expected considering the high level of colour and TOC in the treated water. However, the presence of ammonia in the raw water (0.51 mg/L) and the remaining concentration available immediately after the GAC contactors (0.27 mg/L), indicate that the applied chlorine formed chloramines in the clearwell. Chloramines do not react with organics to form THMs. This observation is confirmed by the reported very low concentration of free chlorine residual in the treated water (0.04 mg/L), and a total chlorine residual concentration of 0.33 mg/L (see Table 4.2).

Most of the total chlorine residual would be present in the chloramine form. A chloramine level leaving the plant of 0.33 mg/L is too low, since it is normally recommended to maintain a level of 2 mg/L to provide sufficient protection against re-growth or contamination in the distribution system.

The average temperature of the groundwater was 12 °C. The raw water temperature for the month of July and August varied from 11 to 12 °C compared to 9 to 10 °C in the winter. The increase in temperature is probably due to residence time in the 1.2 km pipe connecting the well to the treatment plant.

At the time of sampling, the plant was well run with an average turbidity of 0.23 NTU measured at the plant, which is within the MOE guidelines (1 NTU). Turbidity measurement performed at the plant is more reliable than turbidity analysis done at an external lab, since this parameter often changes as a result of the storage effects in the sampling bottle.

Table 4.1 JULY AND AUGUST 1996 SAMPLING FOR ST.PASCAL WATER TREATMENT PLANT
WATER SAMPLES ANALYZED BY NOVAMANN

PARAMETERS	WEEK 1 (15/07/96)	WEEK 2 (23/07/96)	WEEK 3 (30/07/96)	WEEK 4 (06/08/96)	WEEK 5 (12/08/96)	MINIMUM	MAXIMUM	AVERAGE
Turbidity - Raw Water (NTU)	N/A	0.3	0.7	0.8	1.4	0.3	1.4	0.8
Turbidity - Intermediate Water after Filters (NTU)	N/A	0.3	0.4	0.7	1.2	0.3	1.2	0.7
Turbidity - Treated Water (NTU)	0.5	0.2	0.2	0.5	1	0.2	1	0.5
Colour - Raw Water (TCU)	N/A	59	63	56	61	56	63	60
Colour - Treated Water (TCU)	21	21	23	24	22	21	24	22
Colour - Distribution System (TCU)	22	23	24	22	23	22	24	23
pH - Raw Water	N/A	8.43	8.31	7.95	8.34	7.95	8.43	8.26
pH - Treated Water	8.69	8.12	8.19	8.29	8.44	8.12	8.69	8.35
Alkalinity - Raw Water (mg/L - $CaCO_3$)	N/A	572	574	567	562	562	574	569
Alkalinity - Treated Water (mg/L - $CaCO_3$)	572	569	569	554	557	554	572	564
TOC - Raw Water (mg/L)	12.6	12.2	10.4	12.0	12.6	10.4	12.6	12.0
TOC - Treated Water (mg/L)	9.3	8.7	7.4	9.9	9.7	7.4	9.9	9.0
TOC - Distribution System (mg/L)	9.7	9.2	7.4	9.4	10.8	7.4	10.8	9.3
Free Ammonia - Raw Water (mg/L - N)	0.38	0.26	0.36	0.94	0.61	0.26	0.94	0.51
Free Ammonia - Intermediate Water after Filters (mg/L-N	N/A	0.21	0.18	0.53	0.17	0.17	0.53	0.27
Free Ammonia - Treated Water (mg/L - N)	N/A	0.17	0.12	0.37	0.16	0.12	0.37	0.21
THMs - Quenched Treated Water (ug/L)	ND	TR	TR	TR	TR	TR	TR	TR
THMs - Quenched Distribution System (ug/L)	ND	TR	TR	TR	TR	TR	TR	TR

N/A: Not Available
ND: Not Detected
TR: Trace amount detected (Method Detection Limit (MDL) > TR >1/5 MDL)

Table 4.2 JULY AND AUGUST 1996 SAMPLING FOR ST.PASCAL WATER TREATMENT PLANT
OPERATING DATA COLLECTED AT THE WTP

PARAMETERS	WEEK 1 (15/07/96)	WEEK 2 (23/07/96)	WEEK 3 (30/07/96)	WEEK 4 (06/08/96)	WEEK 5 (12/08/96)	MINIMUM	MAXIMUM	AVERAGE
Average Daily Flow (m^3/d)	N/A	140	140	120	140	120	140	135
Turbidity - Raw Water (NTU)	N/A	N/A	0.83	0.89	0.42	0.42	0.89	0.71
Turbidity - Intermediate Water after Filters (NTU)	N/A	N/A	0.31	0.35	0.32	0.31	0.35	0.33
Turbidity - Treated Water (NTU)	N/A	N/A	0.27	0.21	0.20	0.20	0.27	0.23
Temperature - Raw Water (Degree Celsius)	N/A	11	11	12	12	11	12	12
Free Chlorine Residual (mg/L)	N/A	0.02	0.06	0.02	0.07	0.02	0.07	0.04
Total Chlorine Residual (mg/L)	N/A	0.45	0.39	0.19	0.28	0.19	0.45	0.33
Hydrogen Peroxide Residual -Plant Influent (mg/L)	N/A	7.0	2.5	10.0	6.0	2.5	10.0	6.4
Hydrogen Peroxide Residual -Intermediate Water (mg/L)	N/A	0.0	1.5	0.5	0.5	0.0	1.5	0.6
Hydrogen Peroxide Dosage (mg/L)	N/A	N/A	N/A	N/A	N/A	-	-	-
Chlorine Dosage (mg/L)	N/A	N/A	N/A	N/A	N/A	-	-	-

N/A: Not Available

4.2 PROCESS UNIT ASSESSMENT

A very limited experimental treatment study was performed in 1992 on the St. Pascal groundwater supply to evaluate the feasibility to treat the raw water with granular activated carbon (GAC). The results suggested that GAC was capable of providing high quality drinking water meeting all Ontario Drinking Water Objectives (ODWO). Passage of the raw water through a bed of granular activated carbon removed most of the colour and produced a water with a much lower chlorine demand. The chlorine also was noted to bleach much of the colour remaining. A peculiar odour was sometimes associated with the water and tests showed that this could be removed by aeration. An aerator was therefore proposed in the plant design. On the basis of this brief treatment study and subsequent discussions with the MOE, a plant using aeration, GAC contactors and sodium hypochlorite addition was constructed and commissioned in 1992.

Good water quality was obtained for approximately three months and then the finished water quality deteriorated rapidly with high colour and THMs problems. After several months of operation the treated water colour had risen to the same level as the raw water, showing the carbon was inactive or exhausted and was no longer adsorbing NOM. In addition to the strong water colour, the THMs concentrations in the treated water were found to be very high, approaching 900 μg/L.

After about one year, operational problems with the well became apparent. Biological growth was choking the well pump and pipe to the plant, the aeration chamber and the wetwell. Use of chlorine to kill the growth was considered knowing that it would be only partly effective, and would have effects on the downstream carbon adsorbers and possibly reduce their life span. Hydrogen peroxide was tried as an alternative to pre-chlorination. An injection system was set up and 140 mg/L hydrogen peroxide was used to control the biofilm formation. Maintenance doses of 15 mg/L were suggested to control growth and odour in the raw water. This appeared to be effective. Questions about grades of hydrogen peroxide usable in potable water revealed that the much more expensive food grade product was required rather than the less costly technical grade.

Replacement of the carbon contactor beds was suggested as a solution to the community but this option was declined on cost grounds. The estimated cost for the replacement of the two GAC filters is $20,000 per recharge, and four replacements were predicted per year. However, in response to medical concerns the carbon was replaced in early 1996. Water of acceptable but gradually deteriorating quality was in production during early summer 1996.

5.0 PROCESS MODIFICATIONS

5.1 THMs CONTROL

RAL Engineering Ltd and the MOE staff first visited the St. Pascal plant in June, 1996. A review of the operation was made with the operators, Mr. Rodrigue Lafleur and Mr. Robert Cleroux. It was agreed that quarterly replacement of the carbon was not an economically viable solution. Instead the control of the THMs would be attempted with the application of two basic techniques.

1. Enhancement of the carbon adsorption capabilities to reduce operating cost associated with its replacement. It was recommended that the GAC filters be operated as biologically active filters to extend their useful period of operation, and to reduce the concentration of organics in the treated water. In turn, the reduced amounts of organics will produce less THMs after chlorine addition for disinfection.

2. Use of chloramine disinfection as opposed to use of free chlorine to provide a much better control on THM formation.

5.1.1 Precursors Removal

5.1.1.1 Biological Carbon

Biological carbon adsorbers can be made from oil, coal, wood or other carbon containing material. The carbon is treated at high temperature often with steam and with little oxygen for activation. These processes produce carbon particles with very large adsorbent surfaces - mostly internal pores and passages in the carbon particles. When exposed to a wide range of chemicals, the carbon surface adsorbs a layer of molecules by weak chemical attachment.

When all the accessible surface is covered, the carbon is said to be spent or to have exhausted its adsorption capacity. The carbon then requires removal and disposal or heat treatment for regeneration. This process is purely physical/chemical and does not involve activity of micro-organisms. For St. Pascal, the adsorption process will only last a few months as demonstrated in previous years of operation.

Carbon can also be used to support micro-organism growth which will give place to microbiological activity. Instead of relying solely on the adsorption capacity of the carbon, favorable conditions can be developed to promote micro-organism growth on the carbon surface which will use the organics as food, extending the life span and performance of the carbon filter. These micro-organisms are non-harmful bacteria and can be found in a thin layer on the walls of most water mains. Given enough time and nutrients, the bacteria film will consume much of the organics in the water. This process will increase the bacteria mass over time to a point that can block the passage of water and nutrients through the filter. This can cause water to short circuit through cracks forced into the bed and reduce the effectiveness of the bed to remove organics.

To reduce the clogging of the carbon bed the filter is backwashed. The backwash water must flow up through the carbon bed fast enough to fluidize the bed, wash out the excess bacteria growth without washing out the carbon. Eventually, regular backwashing will fail to bring back bed performance due to the total saturation of the carbon. The carbon will then need to be replaced. Colour levels consistently above 25 TCU in the effluent from the second filter should be used to indicate need for bed replacement. After rebedding the filter, the flow should be reversed so the filter with fresh carbon is now downstream of the used carbon bed. The procedure for testing colour is presented in Appendix D.

Promoting the biological activity of the carbon will help compensate for the loss of adsorption capacity that happens over time.

5.1.1.2 Backwash Requirement for the Biological Carbon

Backwashing procedure is required. The backwash water source is the clearwell therefore, a chlorine residual is always present. This chlorine can damage or kill the useful bacteria developing on the GAC and can reduce the performance of the filter as biological process for removal of colour and organics. Backwashes should therefore be limited to the minimum requirement. Based on experience in the plant, short backwash periods lasting about seven minutes at a calculated water rise rate of 9 m/h (6" per minute) is recommended. The upstream filter should be backwashed every 2 weeks, and the downstream filter every four weeks as a minimum. To avoid overloading the backwash receiver tank and the tile bed, a two day delay should separate successive backwashes. The recommended backwash procedure is presented in detail in Appendix D.

Implementing the backwash procedure described above immediately improved the filter operation. The mean life of the carbon bed was extended to 9 months before the colour removal fell below 15 TCU on average. Continued refinement of this backwash procedure may extend carbon life to approximately one year, assuming that the well water quality remains consistent.

5.1.1.3 GAC Contactor Flow Rate

It was recommended to slow the flow rate through the GAC to allow more time for the slow adsorption/bacterial assimilation process. The present EBCT at the plant rated capacity of 6.3 L/s is 15 minutes. Therefore, reducing the flow rate to about half the maximum rate (3.2 L/s) by throttling the flow control valve would increase the EBCT to 30 minutes. This recommendation was implemented by the plant operators, and produced improved water, while maintaining sufficient throughput to meet the daily water demand.

Since the water demand changes seasonally, the operator needs to verify regularly that the flow rate of the water through the carbon beds is throttled to ensure that the plant is operated at least 20 hours per day. Monthly adjustment of the flow rate should take place when the plant fails to meet demand or the clearwell level progressively falls.

5.1.2 Chloramination

Optimization of the removal of organic matter from the water supply alone is usually not sufficient to reduce the formation of THMs when the THMs formation potential is as high as found at St. Pascal. Changing the disinfectant to chloramine is required.

Ammonia combines chemically with chlorine to produce chloramine which is a much less powerful disinfectant than chlorine. Use of chloramine has two consequences relevant to drinking water quality. These are as follows:

1. Chloramine does not react with organics present in the water to form THMs.

2. Chloramine is a less powerful disinfectant than chlorine and care must be taken to ensure this factor does not affect water quality.

Chloramine alone is generally not considered powerful enough for surface water disinfection even when used for many hours at high concentrations. With groundwater, the disinfection requirements are easier to achieve since the more resistant microorganisms to disinfection like cysts are removed as the water moves through the aquifer. Disinfection requirements for groundwater are not well defined in the United States or in Ontario. The AWWA recommends a residual of 1.0 mg/L of chloramine be maintained in the distribution system to prevent re-growth (AWWA, 1993).

The raw water supply contains some ammonia probably originating from local fertilizer use. It was initially hoped that the ammonia present in the raw water would be sufficient to perform chloramination. Experience during this project has shown that background levels of ammonia of the raw water are variable and will not always be high enough to produce chloramines at the required concentration of 1.0 mg/L. Therefore depending on the time of the year, addition of extra ammonia may be required.

Even if the raw water contains sufficient ammonia, a standby source is required. Ammonia can be supplied as a compressed liquefied gas or saturated solution, a gas form, or in dry compounds. Ammonia gas is toxic and corrosive, and handling the concentrated solution requires refrigeration. Consequently, ammonium sulphate in dry compound is preferred. Ammonium sulphate is a crystalline water soluble salt which is not strongly toxic. When required, the ammonium sulphate solution ready for dosing, should be prepared at least weekly. This solution is added to the main water stream at a controlled dosage rate downstream of the carbon contactors, and immediately upstream of the chlorine addition point where there is good turbulence. This treatment has proved satisfactory producing THMs concentrations under 10 µg/L.

5.1.2.1 Dosage of Ammonium Sulphate

The procedure adopted for determining the dosage of ammonia required is as follows:

- Check the concentration of free and total chlorine residual on a water sample taken from the sample valve immediately upstream of the vertical discharge line into the clearwell.
- Adjust chlorine feed to give a total chlorine residual of 2 mg/L at this point.
- Run the plant for half an hour or more, re-sample and measure free and total chlorine. If there is an insufficient amount of ammonia in the raw water, a significant portion of the total chlorine will be present in the free chlorine form therefore, requiring addition of ammonium sulphate.
- In the event that a very small amount of free chlorine is detected, this means that the total chlorine is present in the combined form representing the concentration of chloramine. Therefore, addition of ammonium sulphate would not be required.
- The preparation of the ammonium sulphate solution for a 7 day supply is described in Appendix D.

5.2 OXIDATION

Control of biological growth in the St. Pascal well and connecting system to the carbon adsorbers was achieved before the THMs control study. Excessive quantities were found to be needed when added continuously. Previous rates of addition at 10 to 15 mg/L were apparently supporting aerobic biofilm activity. As a consequence peroxide levels were reduced and maintained to about 2 mg/L at the plant to control odours. Failure to maintain the peroxide residual rapidly resulted in a sulphur odour probably due to anaerobic activity. With a dosage of 15 mg/L a gradual thickening of the biofilm was taking place causing deterioration of the water quality.

Hydrogen peroxide is known to serve as an oxygen supply for bacteria at concentrations below 50 mg/L. Treatment with greater concentrations of peroxide was needed to clear the biofilm from time to time. Regular shock loading at approximately 100 mg/L is now being performed once a week at the well head. This requires less than half the amount of peroxide to provide 10 mg/L continuous dosing and is much more effective in biofilm control and odour prevention. Care is required not to overdose and affect biofilm activity in the carbon contactors.

6.0 CONCLUSIONS

During 1996 and 1997 the St. Pascal Water Treatment Plant was operated with MOE assistance to optimize use of existing equipment and chemicals and to modify the disinfection procedures to avoid THMs formation. The changes instituted produced water with very low THMs concentrations. Work carried out with the cooperation of St. Pascal water plant staff and management has led to the following results:

- Control of THMs levels, previously exceeding 500 µg/L, to well below the current limit of 100 µg/L has been shown possible by using chloramination. The results for water samples taken in July and August 1996 showed only a trace level of THMs at the water treatment plant and in the distribution system. The ammonium sulphate dosing equipment and water sampling tap is already in place. Injection of ammonium sulphate was not needed during the summer 1997 due to natural ammonia levels, however, this may be required periodically.

- The plant can be operated with the carbon contactors in biological mode. In this condition, acceptable treated water with colour below 25 TCU can be obtained from the beds over at least 9 months and possibly for one year before replacing the carbon.

- A carbon replacement was required in the fall of 1997 after only four months of operation. It is suspected that the type of carbon used during the last replacement was not as suitable to support biological growth as other grades. It is expected that cost effective selection of carbon grade and manufacturer will require some trial for this particular process.

- The turbidity of the treated water during the summer 1996 ranged from 0.2 to 0.27 NTU with an average of 0.23 NTU. This is below the ODWO for turbidity of 1 NTU

- Historical data available regarding the level of aluminum residual found in the treated water showed an average aluminum residual of 8.1 μg/L which is much lower than the ODWO of 100 μg/L.

- The performance of hydrogen peroxide applied to control biofouling in the well and raw water pipes has improved by using regular shock treatment rather than continuous addition.

7.0 OPERATING COSTS ESTIMATE

By operating the GAC filters in biological mode, acceptable finished water can be obtained for at least 9 months before replacing the carbon in the beds. The costs for bed replacement to maintain an acceptable treated water quality would be $20,000 per year compared to $80,000 per year if operated strictly as adsorbers and replaced quarterly.

The additional operating cost related to dosing ammonium sulphate could not be estimated accurately since the exact dosage required and the actual period of the year when its addition is required is not known. This is due to the fact that the ammonia concentration in the raw water is not constant through the year. The chemical costs, if any, will be minor.

Adjustments in the manner of use of the hydrogen peroxide applied to control biofouling by using regular shock treatment rather than continuous addition is likely to reduce peroxide usage to less than 50% of the current rate for a saving of about $20,000 per year.

Work undertaken during the THMs optimization study in 1996 and 1997 demonstrated that the St. Pascal Water Treatment Plant can be operated to produce safe water at reduced but still considerable operating costs.

GLOSSARY AND LIST OF ABBREVIATIONS

Alum : aluminum sulphate

CT : Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.

d : day

°C : degree Celsius

DWSP : Drinking Water Surveillance Program

ECR reagent : Eriochrome Cyanine R

FID : Flame Ionization Detector

ft : foot

G : flocculation energy gradient

Gt : flocculation energy

GC/MS : Gas Chromatograph / Mass Spectrometry

GAC : Granular Activated Carbon

g : gram

h : hour

HFS : hydroxylated ferric sulphate (Ferriclear)

ICP : Inductively Coupled Plasma Atomic Emission Spectoscopy

IG : imperial gallon

kW : kilowatt

L : litre

L/cap.d : litres per capita per day

L/s : litres per second

m : metre

m^2 : square metres

m^3 : cubic metres

m^3/d : cubic metres per day

m/h : metres per hour (equivalent $m^3/m^2.h$ - filtration rate)

μg/L : micrograms per litre

mg/L : milligrams per litre

mm : millimetre

mL/min : millilitres per minute

min : minute

NTU : Nephelometric Turbidity Unit

OCWA : Ontario Clean Water Agency

ODWO : Ontario Drinking Water Objective

% : percent

PACL : polyaluminum chloride

PVC : polyvinyl chloride

lb : pound

rpm : revolution per minute

SOR : Surface Overflow Rate

SWTR : Surface Water Treatment Rule

T_{10}/T : This factor describes the baffling condition in the clearwell, and represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.

TOC : Total Organic Carbon

THMs : Trihalomethanes

TCU : True Colour Unit

W/V : weight/volume

REFERENCES

American Water Works Association Research Foundation - Optimizing Chloramine Treatment, 1993.

Environmental Science and Engineering Magazine. Drinking water Update - The Facts About Human Health and Aluminum in Drinking Water, January, 1997.

APPENDICES

Plant Survey

Appendix A

PLANT **Township of Clarence, St. Pascal Water Treatment Plant**
Shipping Address: Town Hall of Clarence, Box 70, 415 Lemay St., Clarence Creek K0A 1N0

Tel: (613) 488-2570 Fax: (613) 488-2324

PREPARED BY: R. LeCraw
DATE: Plant Visit June 12, 1996

STAFF:
Superintendent: Mr. Rodrigue Lafleur
Names of Operator: Bob Cleroux
No. of Operators: 2
Plant Operated With Staff : Approx. 1-2 hours per day
Certified: Yes

PLANT CAPACITY:
Average Daily Flow: 1.7 L/s (148 m^3/d - 1995)
Maximum Daily Flow: 3.2 L/s (280 m^3/d - 1995)
Rated Plant Capacity: 6.3 L/s (544 m^3/d)
Population Served: 350 people

OPERATING AUTHORITY: Township of Clarence

YEAR OF CONSTRUCTION: 1992

SOURCE OF RAW WATER: 2 Wells located approximately 2 km north of the community

WATER CHARACTERISTICS:

	RAW	**TREATED**
Colour:	54 - 97 TCU	26 - 42 TCU
Turbidity:	0.7 - 9.0 NTU	0.3 - 1.0 NTU
pH:	7.2 - 8.5	7.8 - 8.4
Alkalinity:	562 - 574 mg/L	554 - 572 mg/L

CHEMICALS:
Pre-oxidant: Type: Hydrogen Peroxide 35% (H_2O_2)
Dosage: 15 mg/L
Injection Point: Well

Post-disinfection: Type: Sodium Hypochlorite (12%)
Dosage: 12 - 15 mg/L (Summer 1996)
Injection Point: Post GAC prior to clearwell

ANALYSIS DONE AT THE PLANT:
- Chlorine Residual
- H_2O_2 Residual
- Apparent Colour
- On-line Turbidity on finished water

LAB EQUIPMENT AVAILABLE:
- Chlorine DPD colour comparitor
- DR 700
- H.F. Scientific Colour Comparator Test Kit
- pH meter
- Hach 2100A Turbidimeter

CHEMICALS METERING:

TYPE	DOSAGE	CONTROL	CONDITION
Pre-oxidant			
Hydrogen Peroxide:	Manual		
Post-Disinfection:			
Sodium Hypochlorite (3) Prominent 44 Feed Pumps Positive Displacement	Pump Capacity: 4 L/h	Well Water Flow	Good

PROCESS CONFIGURATION:

INTAKE:	TYPE				CONDITION	NOTES
Well	Drilled Approximately 15 m (50 ft) deep				Good but poor water quality	
SCREENING:	TYPE	NO	DIMENSIONS		CONDITION	NOTES
Well Screen		1			Good	
LOW LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Vertical Turbine	2 (1 in duty, 1 in standby)		6.3 L/s (each) with a flow control valve to limit the rate to 5.7 L/s (5 HP)		
AERATION CHAMBER:	TYPE	NO	DIMENSIONS	VOLUME	CONDITION	NOTES
Small concrete tank with 4-stage steel splash plates		1		6.2 m^3	Good	Small but effective in removing methane and H_2SO_4.
HIGH LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Worthington Vertical Turbine	2 (1 duty, 1 standby) VFD drives		2.5 L/s to 16.07 L/s (29 HP)		
MIXING:	TYPE				CONDITION	NOTES
None						
FILTERS:	TYPE	NO	DIMENSIONS	CAPACITY	CONDITION	NOTES
GAC contactors	Calgon	2 in Series	2.13 m (7') dia , 2.3 m (7.6') high Filter area: 3.56 m^2	6.4 m/h (@ 6.3 L/s) EBCT: 15 min	Tanks are in good shape. Carbon near exhaustion with significant colour breakthrough.	
CLEARWELL/: ON-SITE RESERVOIR		NO	DIMENSIONS	VOLUME	BAFFLED: No	NOTES
		1	12 m x 5.95 m x 3.5 m deep	428 m^3	Two cells no baffles in cells but can route flow from GAC to end of one cell down length through a gate and back to the high lift pump	

PLANT CONTROL (Prior to June 1996):

Flow (Manual Set/Auto): Manually set at nominal well pump capacity.

Level: Well on/off controlled from clearwell level.

On/Off: Plant runs at fixed rate until clearwell filled then shuts off.

PROCESS MONITORING:

	INSTRUMENT	MONITORING FREQUENCY	LOCATION/ NOTES
Turbidity:	Hach 2100 P Turbidimeter	2 x Daily	Finished water.
pH:	Not measured		
Free Chlorine:	DPD colour Comparator	2 x Daily	Lab sink (connected to high lift pump output).
Total Chlorine:	DPD colour Comparator	2 x Daily	Lab sink connected to high lift pump.
Temperature:	Alcohol in glass Thermometer	Periodically	Lab sink.
Aluminum Residual:	N/A		
Colour:	DR 700 Colorimeter	Daily	Lab sink
Other:			

ISSUES PRIOR TO JUNE 1996:

Fresh carbon is effective at removing colour and THMs precursors but the first load of Calgon (exact type unknown) lasted only 3 months before almost total colour breakthrough and extremely high THMs levels were developed. The carbon costs is approximately $17,000 to replace. The carbon was replaced around March 1996, and as of the visit of June was performing somewhat better in that the final colour was reduced to approximately 15 TCU from a raw water colour of approximately 60 TCU. It has been observed that there is an approximate 50% reduction in colour on slow passage through each of the contactors . THMs were marginally over the 100 μg/L level.

In June 1996, the plant staff were dosing 12 to 15 mg/L chlorine to achieve a 0.5 mg/L free residual.

The high chlorine demand may be due to the organics breakthrough from the GAC, a high H_2O_2 residual and/or free ammonium in the well supply.

Process optimization efforts will be directed at achieving the optimum level of biomass in the GAC to improve longevity. This will be accomplished by setting a backwash schedule and monitoring carbon performance and life. Initially, a backwash frequency of about two weeks was suggested. Next, the use of hydrogen peroxide will be reviewed to establish whether a residual was passing through the GAC and creating a chlorine demand. Finally, the option of chloramination will be investigated. With the natural ammonia it may be possible to cut back on the applied chlorine dose and stay with the chloramine range. If necessary an ammonium sulphate feed system could be installed to ensure sufficient free ammonia is available.

Copies of the pilot testing report will be requested from McNeely Engineering to review the data used for the carbon selection. Alternative carbon sources could be further investigated.

INFORMATION REQUIRED:

- Copy of Certificate of Approval.: Yes
- Copy of MOE reports if available: Yes
- Copy of monthly flows for the previous year: Yes
- Copy of the monthly analysis for the previous year to evaluate plant performance for the raw water and plant effluent.

Analytical Procedures used by Novamann

Appendix B

Detection Limit and Analytical Method Reference used by Novamann

PARAMETERS	MINIMUM DETECTION LIMIT(MDL)	ANALYTICAL METHOD	METHOD REFERENCE*
THM	6 μg/L	Purge &Trap GC/MS	EPA 624
TOC	0.1 mg/L	UV/PEROX/FID	EPA 9060
residual aluminum	0.025 mg/L	ICP	EPA 6010
turbidity	0.1 NTU	Turbidity Meter	APHA 2130
true colour	1 TCU	Colourimetric	APHA 2120
pH	0.01	pH Meter	APHA 4500H
alkalinity	1 mg/L - $CaCO_3$	Titration	APHA 2320
ammonia + ammonium	0.05 mg/L	Colourimetric	APHA 4500
anions (NO_3, Cl, SO_4, F)	0.1 to 0.5 mg/L	Ion Chromatography	EPA 300.0
conductivity	1 umho	Conductivity Meter	APHA 2510
lead	0.002 mg/L	Graphite Furnace	EPA 7421
metals		ICP	EPA 6010
nitrite	0.1 mg/L	Colourimetric	APHA 4500
orthophosphate-P	0.005 mg/L	Colourimetric	APHA 4500

Note * : EPA : Environmental Protection Agency
APHA : American Public Health Association

Certificate of Approval

Appendix C

Z-122

RECEIVED JUL 4 1991

Ministry of the Environment
Ministère de l'Environnement
Ontario

250 Davisville Avenue
Toronto, Ontario
M4S 1H2

250, avenue Davisville
Toronto (Ontario)
M4S 1H2

APPROVALS BRANCH
3rd Floor
Tel. (416)440-3707
Fax (416)440-6973

June 25, 1991

Township of Clarence
Box 70,
415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

Attention: Mr.R.Lalonde,
Clerk-Administrator

Dear Mr. Lalonde:

Re: Township of Clarence
St. Pascal Baylon Water Works System
Certificate of Approval No. 7-0449-89-006
Contract No. 2

On February 14, 1991, this Ministry received a final submission, including a design report, engineering drawings and contract documents, for approval to construct well Pumping stations, a Water Treatment Plant with an in ground storage reservoir in the Township of Clarence from the consulting firm McNeely Engineering Limited, in accordance with Condition No.2 of the certificate of Approval No. 7-0449-89-006 dated August 18, 1989.

Staff of the Municipal Approvals Section have reviewed the final submission, and found it to be in accordance with this Ministry's guidelines. We are, therefore, satisfied that Condition No.2 on the above mentioned certificate has been fulfilled for those works described below. You may now proceed with the construction of these works under contract No.2.

Well No. 1 (D11 Production Well) Pumping Station

Construction of a pumping station having overall dimensions 4m x 4m, on Lot 10, Concession 5, approximately 260 m west of County Road No.1 to house the existing well No.1, equipped with a submersible well pump having a capacity of 5.7 l/s, standby chemical feed system consisting of a chemical pump capable of dosing sodium hypochlorite solution at a rate of 4 l/h, and a solution tank, station piping, controls and approximately 24 m of 150 mm diameter supply main from the well to the existing main.

...../2

Well No. 2 (D12 Standby Well) Pumping Station

Construction of a pumping station having overall dimensions 4m x 4m, on Lot 10, Concession 4, fronting Country Road No.8 and approximately 100 m north of County Road No.1 to house the existing well No.2, equipped with a submersible well pump having a capacity of 5.7 l/s, standby chemical feed system consisting of a chemical pump capable of dosing sodium hypochlorite solution at a rate of 4 l/h, a solution tank, station piping, controls and approximately 15 m of 150 mm diameter supply main from the well to the existing main.

Water Treatment Plant

A building having overall dimensions 13.1 m x 16 m on Lot 10, Concession 4, fronting County Road No.1 at Township Road No. 103 consisting of the following:

- an aeration chamber consisting of a below grade storage volume of 6.2 m^3 and equipped with:
  four staggered steel plates having an effective surface area of 2.6 m^2 to provide cascade aeration;
  forced air ventilation system;

- a below grade 29.4 m^3 capacity pre-chlorination/low lift pump wet well equipped with:
  - two low-lift vertical turbine pumps (one duty and the other standby) each having a rated capacity of 6.3 l/s with a flow control valve to limit the rate of pumping to 5.7 l/s;
    a level control system to on/off well pumps and low-lift pump;

- granular activated carbon adsorption system consisting of:
  - two down flow pressure filtration type Granular Activated Carbon Columns each with maximum column loading of 12 $m^3/m^2/h$ to operate in series;
  - in-built piping system to change the sequence of operation, back wash piping system;
    pressure controls, automatic/manual back wash system;

...../3

- a two-compartment clearwater well/in ground storage reservoir having a total capacity of $500\ m^3$, equipped with:
    - two (2) variable speed vertical turbine (one duty and the other standby) high-lift pumps each capable of delivering water to the existing distribution system within a range of 2.5 l/s (average) and 16.07 l/s (peak hour);
    - clear well level controls, pressure sensors, by-pass/recirculation;

- a chemical feed room equipped with:
    - three (3) chemical feed pumps each capable of dosing sodium hypochlorite solution at a maximum rate of 4 l/h
    - three (3) chemical solution tanks each having a capacity of 228 litre and fitted with a mixer;
    - piping system to dose sodium hypochlorite solution after aeration system and after carbon filtration;

- a laboratory room equipped with:
    - laboratory equipments;
    - a chlorine residual analyzer together with a recorder and high/low residual chlorine alarm system;
    - a turbidity meter together with a recorder;

- a mechanical room equipped with:
    - a 60 KW standby diesel generator set;
    - a 912 l capacity fuel tank with a concrete containment facility;
    - fuel piping system, exhaust gas system and controls;

- a wash room consisting of a water closet, a shower cabinet, a laboratory sink, hot water heater, domestic water and sanitary system;

Filter backwash and sewage disposal system consisting of a 25,000 l capacity holding tank, two (2) submersible sewage pumps each rated at 2 l/s, a 3,700 l capacity septic tank and a tile field,

together with flow meters, telemetry system, alarm system, electrical/electronic control system, all station/yard piping system, heating/ventilation system.

...../4

I would remind you that the diesel generator set establishes a requirement for an approval under Section 9-(1) of the Environmental Protection Act (EPA). The Act requires that no person shall, except under, and in accordance with an approval issued by the Director: construct, alter, extend or replace any plant, structure, equipment, apparatus, mechanism or thing that may discharge or from which may be discharged a contaminant into any part of the natural environment other than water.

Also, the septic tank and tile field disposal system requires approval under Section 64 of the EPA.

This letter as such constitutes part of the above noted Certificate of Approval.

Copies of this letter of compliance are being forwarded to persons indicated.

Yours truly,

W. Gregson, P. Eng.,
Director,
Section 23 & 24 O.W.R. Act

RM/nm
cc: B. Ward, Reg. Dir., MOE SE Region
R. Brown, MOE Project Engineering
McNeely Engineering Limited

Operating Procedures

Appendix D

Revised/New Operating Procedures - St. Pascal Water Treatment Plant

D.1 Carbon Bed Replacement

The plant has two downflow carbon beds operated in series so the water passes through the partly exhausted carbon first and the cleanest carbon bed last. Water colour shall be measured using the Hach DR7OO colourimeter available at the plant at 450 nm, or the Hach DR2000 spectrophotometer at 455 nm. The colour should be checked weekly.

All water samples for colour measurement should be filtered using 0.45 µm or finer membrane filters. Colour shall be measured using the same well-cleaned scratch-free vial for zeroing with colour free water and for plant effluent. Vials may be cleaned using an ultrasonic bath or dishwasher but should be discarded once the fire polish is removed from the vial surface or scratches become visible.

Colour levels consistently above 25 TCU in the effluent from the second bed shall be used to indicate need for bed renewal. Under no circumstances shall colour be allowed to consistently exceed 30 TCU.

After rebedding the filter, the flow sequence of beds shall be reversed so the fresher carbon is downstream of the partly used carbon bed.

D.2 Carbon Bed Backwash

The St. Pascal GAC contactors are to be operated to encourage bacterial growth on the carbon. Backwash must take place to wash out excess mass, or carbon bed life will be reduced. Since chlorinated water has to be used for backwash, care must be taken to restrict the backwash rate to 9 m/h (6 inches per minute) to avoid washout and loss of carbon. The maximum time for backflow must be restricted to less than seven minutes. This ensures that the top of the bed is never exposed to chlorine in the backwash water, which may kill biological activity.

The upstream bed should be backwashed every 2 weeks and the downstream bed every 4 weeks as a minimum. Failure to backwash regularly will lead to loss of colour removal activity due to partial blockage/channelling of the flow. To avoid overloading the backwash receiver tank and the tile bed, a two day delay should separate successive backwashes.

D.3 Plant Operating Rate Adjustment

Carbon adsorbers operate at highest colour removal efficiency when the water passes through as slowly as possible. Since water demand changes seasonally, the operator needs to check regularly that the flow rate of water through the carbon beds is throttled to ensure the plant operates for at least 20 hours per day. Monthly adjustment of this rate should take place when the plant fails to meet demand and clearwell levels progressively fall or the operating period each day drops to less than 20 hours.

D.4 Chlorine Flow Adjustment

After flow adjustment by throttling has taken place the chlorine addition rate must be adjusted. Total chlorine levels at the extreme ends of the distribution system must be held at greater than 1.0 mg/L and the recommended plant clearwell level is 2.0 mg/L. The chlorine flow adjustment is to be made in proportion to flow through the carbon beds. This should be checked by timing the drop in level in the chlorine pump calibration tube. The chlorine tank level must be checked daily to avoid underdosing due to the pump check valve sticking or any diaphragm leaks.

D.5 Chlorine Level Checks

A water sample must be taken with the plant running for at least one hour to measure the chlorine residual. Make sure the sample bottle is glass and is completely filled with no air space under the cover. Allow the sample to stand for 30 minutes and then measure total and free chlorine using the DPD procedure with the DR7OO or DR2000.

Samples taken from the clearwell or sample valves on the line from the high lift pumps may respond slowly to chlorine change due to the relatively high contact time in the clearwell. These samples are acceptable for daily monitoring but should not be used for adjustment of chlorine or ammonia feed.

D.6 Ammonium Sulphate Feed

The St. Pascal groundwater has a naturally high THM formation potential. In the presence of free chlorine, THM will be formed from the natural organics in the water leading to THM exceeding the health objective level of 100 micrograms per litre. Avoiding doing disinfection using free chlorine is therefore recommended. Natural ammonia levels in the groundwater may be enough to perform chloramination. But at some periods, ammonium sulphate may need to be added to supplement the natural levels of ammonia.

The procedure for determining if ammonia is needed is as follows:

- Check free and total chlorine on a sample taken from the sample valve on the carbon bed effluent line as described in section D.5.
- Adjust chlorine feed to give an immediate total chlorine residual of 2 mg/L.
- Run the plant for half an hour or more, re-sample and measure free and total chlorine.
- If there is an insufficient amount of ammonia in the raw water, the majority of the total chlorine will be present in the free chlorine form therefore, requiring addition of ammonium sulphate. In the event that a very small amount of free chlorine is detected, this means that the total chlorine is present in the combined form representing the concentration of chloramine. Therefore, addition of ammonium sulphate would not be required.
- Enough ammonia solution should be made up for 7 days supply.
- Eighty-six percent (86%) of the weight of free chlorine used in one week production must be added as ammonium sulphate to the water for exact balancing. A 20% extra is suggested. Do not add more than a 20% excess of ammonia since this will encourage nitrifying bacteria in the distribution system to multiply and grow.
- Dissolve the calculated amount of ammonium sulphate (food grade) in 200 litres of water.
- Adjust the ammonia solution pump using the pump calibration tube to add this amount of solution over one week of projected plant operating hours.

D.7 Hydrogen Peroxide Flush

The well supplying St. Pascal is rich in nutrients. As a consequence, all the surfaces of the well and 1.2 km pipeline connecting the well to the plant are covered in an active biolayer. Given time for growth, this biolayer thickens and anaerobic activity starts up lending an offensive odour to the water. To control this biolayer high concentrations of peroxide must be added on a once per week basis at the well head. With the well pump turned off and using the small electric pump in the wellhead building, transfer 40 to 50 litres of 35% peroxide (food grade) to the well. Allow to stand for a minimum of 60 minutes then throttle the well pump, turn the well pump on, and then after 15 minutes return the throttling valve to normal position.